A Usability and Motivation Analysis of Laboratory Manuals for Empowering Non-Science Students in Chemistry

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ABSTRACT

Well-designed laboratory manuals enhance usability, motivate learning and improve experimental skills. This study explores the relationship between usability and motivation in chemistry education for pre-university non-science students, specifically through the effectiveness of a laboratory manual. An online survey was conducted using a quantitative approach with 76 students from four branches of University Technology MARA in Malaysia. Statistical analysis indicated a significant positive correlation between usability and motivation, emphasizing the role of well-crafted laboratory manuals in developing practical skills and generating interest in chemistry. Key design elements such as clarity, ease of understanding, and relevance were assessed with the ADDIE model, while motivation factors were measured through Keller's ARCS model. The findings highlight the value of customized instructional materials in supporting education for sustainable development (ESD), especially for non-science students. This study offers valuable insights for improving STEM education, promoting sustainability, and advancing interdisciplinary learning in challenging fields like chemistry.

Keywords: Chemistry pedagogy, curriculum design, practical learning, hands-on experiment, laboratory engagement

INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education is increasingly emphasized in educational systems worldwide, including Malaysia. However, [1] assert that incorporating education for sustainable development (ESD) into the fundamental curricula of STEM subjects poses a considerable challenge. Nevertheless, [2] finds that the effectiveness of ESD in STEM classrooms is evident when it is connected to real-world issues. The application of ESD concepts, tied with suitable pedagogical techniques within the realm of science, is identified as beneficial for encouraging a desirable understanding, skills, and values among students [3]. Incorporating ESD concepts into STEM subjects, especially in science, provides students with a solid scientific foundation in science and strengthens their ability to make informed decisions on sustainability issues. The relevance of ESD knowledge through science subjects is essential in the students' daily lives and contributes significantly to fostering a more sustainable future [4]. To meet the challenges and expectations of a STEM-driven economy, the Malaysian government has highly valued STEM education to catalyse the nation's development into a developed country. Accordingly, the Malaysia Education Blueprint 2013–2025 is a roadmap introduced by the Ministry of Education to improve and strengthen STEM education. However, the study reported by [5] shows that STEM education has drawn a lot of attention due to the drop in the number of secondary school students choosing to study science. Students may find science subjects less relatable or connected to real-life applications, particularly if laboratory and classroom experiences lack relevance to their daily lives or potential future careers. This issue can discourage students who do not immediately see the practical benefits of science education, pushing them to opt for other streams.

Therefore, University Technology MARA (UiTM) Malaysia has taken the initiative to offer open enrolment for non-science students to further their tertiary level of education in the sciences field under the Pre-diploma programme (Science). The pre-diploma programme provides a unique academic path for Sijil Pelajaran Malaysia (SPM) graduates who do not meet the fundamental qualifications required to study science courses at a public university. Given the extensive scope of STEM education, this paper will narrow its focus to chemistry. This decision is based on recognising chemistry as a "central science", indicating that a solid grasp of chemistry is crucial for comprehending other scientific disciplines like physics, biology, geology, and environmental science [6]. Previous research has demonstrated that chemistry in science plays a role in all three aspects of STEM education: STEM subject, STEM field, and STEM approach [7][8][9] and has become one of the challenging subjects for non-science students [10].

In promoting ESD within chemistry education, this study adopted the framework designed by Rauch (2015) to empower and assist educators in implementing ESD. [11] specifically presents four fundamental models addressing sustainable development issues through formal chemistry education, and the initial model emphasizes the principles of chemistry in laboratory science education practices. Chemistry is a discipline rooted in experimentation. The significance of conducting experiments extends beyond merely demonstrating chemical principles. [12] highlights that the laboratory serves as a vital space where students acquire the skills and mindset necessary to practice chemistry actively and develop into scientists through engagement in scientific experiments and discourse. A scientific experiment is a process to discover what happens in particular conditions, either to test theories or to provide scientific knowledge. The process involves observations and actions that require certain skills to understand the problem, the objective of the experiment, skills in making measurements and handling apparatus and instruments, responsiveness to certain conditions, and reporting. The skills can be gained through laboratory practices under the supervision of experts such as the lecturer and laboratory assistant. The lecturers or teaching assistants may need to monitor laboratory experiments involving several groups or individuals simultaneously performing the same or different tasks. It requires sufficient time to handle the students; thus, laboratory documentation or laboratory manuals may assist them in executing experiments properly and with minimum supervision.

The good design of the laboratory manual can be seen through its usability; the content presents how users should understand and meet their expectations. According to [13], usability studies focus on assessing the product and how the laboratory manual helps users achieve their specific goals quickly, successfully, and satisfactorily. Despite the emergence of new technologies in education, hard copies of laboratory manuals are still the most often utilised source material for most classroom environments and for conducting teaching experiments. A chemistry laboratory manual is a valuable tool used in laboratory settings to guide students in conducting experiments and understanding chemistry concepts. It is a comprehensive reference and instructional guide outlining various laboratory procedures, safety precautions, data collection methods, and data analysis techniques.

Therefore, in this study the chemistry laboratory manual is designed specifically for non-science pre-diploma level students taking general education chemistry classes. The manual helps students understand the basic concepts of chemistry with easy-to-follow instructions and color illustrations throughout the book.

LITERATURE REVIEW

The Addie Model

Table I shows the literature on developing learning materials, such as module and laboratory manuals. All the learning materials were created by applying the ADDIE Model. This indicates the prominent model used in designing and developing learning materials. The ADDIE Model is commonly selected and widely recognised as a leading strategy in the development of the module, as indicated by its incorporation into multiple instructional models [14],[15],[16]. This model is particularly suited to complex learning settings due to its systematic module construction guide and the inclusion of an assessment mechanism for each phase [17]. The ADDIE Model consists of five phases: (1) Analysis, (2) Design, (3) Development, (4) Implementation and (5) Evaluation.

Literature on developing learning material that adopted the ADDIE Model and evaluation phase aspect.

Development of learning material	Evaluation aspect	Respondent	Authors
Biology laboratory manual	Content, language, presentation	30 Biology students	[15]
Physic laboratory manual	Content quality, technical quality, instructional quality	Engineering students	[18]
Lecture Manual in Animal Pests and Diseases, Laboratory Manual in Animal Nutrition, and Laboratory Manual in Poultry Production	Content, organisation of usability, evaluation, language	20 Agriculture students	[19]
Biology laboratory manual	Skills, knowledge, report	30 Biology students and teachers	[20]
Actuary Mathematics module	Layout, Clarity objective, presentation, content	40 Actuary lecturers and 60 students	[14]
Chemical Entrepreneurship (CEP) module	learning outcomes, enhancement activities, and reflections	Chemistry pre-university lecturers and science stream pre-university students	[16]
Thermal control laboratory manual	content quality, advantages of the thermal kit, and skills that students gained	78 Engineering students	[21]

The evaluation phase involved content experts, teachers, and students. Aspects emphasised in the evaluation phase are layout, content, organisation/ presentation, language, objectives, learning outcome, and usability/feasibility. For instance, [15] developed an Inquiry-Based Laboratory Manual for Biology Education students, revealing that the highly practical aspect of evaluating the laboratory manual is clarity of presentation, ease of understanding, and ease of use. The content met the assessment indicators, conforming with the learning objectives and competencies students were required to achieve.

On the other hand, other academics emphasised the content's internal elements and connected the design features to how the book was organised and aligned with the syllabus [22]. The findings are in agreement with the results of [18], who obtained content quality as the first rank, followed by instructional quality and technical quality in assessing the usability of the manual in Physics. The experts strongly believed that the content was scientifically adequate and accurate, emphasised active learning, was relevant to the objectives, was well organised, evaluated student learning according to the objectives, allowed the development of multiple intelligences, was supported by suitable illustrations and tasks to students, and was aligned to the curriculum. Hence, the manual was applicable to be implemented to facilitate students in conducting laboratory experiments. In addition, a good laboratory manual offers various experiments and activities covering different topics and techniques. This variety exposes students to various laboratory skills, including measurement, observation, data analysis, and critical thinking [20][21][15]. By engaging in diverse experiments, students can develop a broad set of laboratory skills applicable across various chemistry contexts.

Furthermore, by integrating theory and practice, the laboratory manual includes relevant theoretical concepts and background information about the experiments. This helps students understand the underlying principles, chemical reactions, and phenomena they investigate. Therefore, the laboratory manuals may enhance comprehension and reinforce the connection between theory and practical application [20]. According to [19], language is also one of the important technical aspects of designing the laboratory manual. The language used must be clear, accurate, and communicative.

Additionally, the vocabulary used within the context of the discipline and the manuals should not contain grammatical or spelling errors [18]. [21] assert that the terms and symbols should be presented consistently to prevent student confusion. Hence, a chemistry laboratory manual was designed by adopting the ADDIE Model in this current study. A designed chemistry laboratory manual provided experiment instructions, which are written step-by-step instructions for conducting specific experiments.

The laboratory manual outlines the required apparatus, materials, equipment, and chemicals and the following procedures. The guidance ensures that experiments are performed accurately and consistently, promoting reliable and reproducible results [23]. The chemistry laboratory manual also includes relevant theoretical concepts and background information about the experiments.

Moreover, the laboratory manual contains data tables and instructions on how to record experimental data accurately. This may help students with appropriate data analysis techniques, calculations, and graphing methods [24]. The guidelines enable students to organize and interpret their data effectively, facilitating the extraction of meaningful conclusions from their experiments. The laboratory manual may help establish consistency and standardisation in laboratory practices. Hence, different students can achieve comparable results by following the prescribed procedures and methodologies outlined in the manual. This is especially important in educational settings and scientific research, where reproducibility and accuracy are crucial [25]. The designated chemistry laboratory manual is also a reference source beyond the laboratory. It includes information on chemical properties, safety symbols, measurement units, and formulas. Thus, students can consult the laboratory manual to refresh their knowledge, review concepts, or find quick answers to questions related to experiments or chemistry in general.

Other than that, safety is of utmost importance in a chemistry laboratory. Therefore, the content of the prepared chemistry laboratory manual also includes detailed safety guidelines for handling hazardous materials, using protective equipment, and managing waste disposal. By following the instructions, laboratory personnel can minimise the risk of accidents, injuries, and exposure to harmful substances, especially for non-science students unfamiliar with laboratory safety.

The ARCS Model

Previous research focused more on the usability of developing learning material, yet very limited studies on the relationship between the usability of learning material and motivation to learn the subject. [26] and [27] provide a review of the good design of the laboratory manual that may motivate students to learn chemistry, especially in improving their practical skills, and increase students' attention and confidence.

Generally, motivation is the desire to choose what they want to perform and commit to it [28]. [29] state that motivation is "often seen as a condition that energises (or de-energises) behaviors," and many motivation theories in education are highly associated with performance. Therefore, when students are highly motivated, they are likely to attain high learning achievement. However, this study does not evaluate motivation through performance. This study used the ARCS Model to measure motivation through four dimensions: Attention, Relevance, Confidence, and Satisfaction [28]. [28] defines the dimensions as follows: (1) attention is defined as capturing students' interest and stimulating their curiosity to learn, (2) relevance is defined as meeting students 'personal needs, (3) confidence is defined as facilitating students to believe they will succeed, and (4) confidence is defined as strengthening achievement with rewards either externally or internally. Figure 1 illustrates the dimensions of motivation according to [28].

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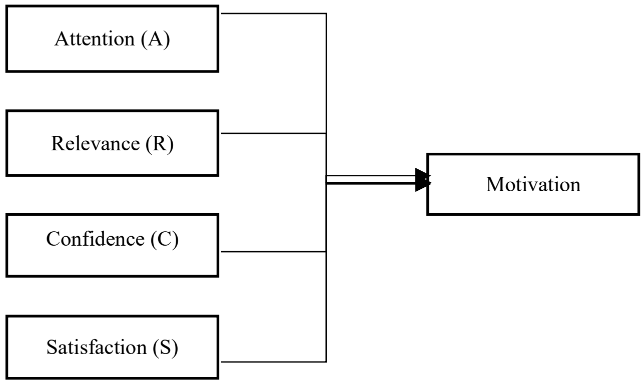

Figure 1. ARCS Model [28]

However, few have specifically examined how non-science students interact with these manuals in terms of usability and motivation. For instant [42] examined students' performance using traditional lab manuals but focused on majoring in chemistry, not non-science students. Meanwhile, [16] investigated students' conceptual understanding in chemistry labs but did not explore the manual as a learning tool.

Hence, considering this framework and models, the objectives of the present study were twofold. The first objective was to evaluate the usability of a chemistry laboratory manual designed for pre-university non-science students with limited knowledge and experience handling laboratory experiments. The other objective was to identify the correlation between usability and motivation among non-science students conducting chemistry experiments through the laboratory manual.

The motivation was measured using the ARCS Motivation Model, which has four dimensions (Attention, Relevance, Confidence, and Satisfaction). Understanding the motivation dimensions of learning chemistry through the laboratory manual can help non-science students demonstrate better in laboratory assessments. The outcomes of such current studies are useful for giving information and improving the usability of prepared learning material in management actions. Specifically, incorporating these concepts into the chemistry subject strengthens societal responsibility towards the environment, economy, and social dimensions and, more significantly, fosters an increased societal understanding of the importance and necessity of education for sustainable development.

METHODOLOGY

Research Design and Approach

This research is using a quantitative descriptive research design to assess the usability of the chemistry laboratory manual and its effect on student motivation. The research consisted of experimental work conducted in a laboratory and a survey-based evaluation of students' perceptions once they completed the experiments. The combination of hands-on laboratory activities with post-experiment feedback provides research results that reflect the real world of usability and motivational effects.

Subjects

Evaluation of designated modules or manuals is usually conducted by both students and teachers who are using the materials for teaching and learning purposes. However, this paper only presents the results from students as respondents. The type of respondents was selected based on the research objectives and for the purpose of this research. A census study involving 83 students who registered in Introduction to Chemistry I (CHM011) in the 2022/2023 academic session. Over a 12-week period, students completed eight laboratory experiments with the prescribed chemistry laboratory manual. The manual provided guidance for every experiment, specifying safety protocols, how to use apparatus, and guidelines for writing reports. After conducting all the experiments, students were requested to respond to the laboratory manual evaluation survey questionnaire that assesses usability and motivation to learn chemistry. The age of the students who registered for pre-science courses for non-science students ranged from 18 to 21. The students had no experience in handling chemistry experiments in their secondary education. A pre-science course named Pre-Diploma in Science (STEM-C and Arts Streams) is offered at University Technology MARA in four states located in Malaysia, namely Kuala Pilah, Negeri Sembilan (KP), Permatang Pauh, Pulau Pinang (PP), Pasir Gudang, Johor (PG) and Mukah, Sarawak (M). Informed consent was given by individual respondents and confidentiality and verbal consent satisfied ethical requirements.

The prepared chemistry laboratory manual consists of three main sections: laboratory safety, laboratory apparatus, and laboratory notebook and report guidelines. The chemistry laboratory manual comprises eight experiments for six topics in a course, namely Introduction to Chemistry I (CHM011), and each chapter includes the assessment question. The chemistry laboratory manual contains 80 pages and is presented in an A5 booklet. The students relied on the laboratory manual for all experiments completed within 12 weeks. At the end of the period, all registered students were requested to complete a survey instrument. The survey instrument for this research was designed by adapting two validated instruments: the usability instrument by [30] and the motivational instrument by [28]. The instrument was divided into two sections; the first was a demographic with seven questions. The second section covered the usability and motivational items and consisted of 20 questions. The original instrument used English; thus, to eliminate the English language barrier among students, the survey instrument was modified using two languages, English and Malay. A five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) was used for section 2 items, in which one was indicated as strongly disagree while five was indicated as strongly agree. Three experts in Linguistics validated the language of the instrument. All items are shown in Table II.

Table II. Questionnaire Items (Source: Adapted From [28]).

Item Code	**Construct/Dimension**	**Question**
Usability		
U1	Practical consideration	The chemistry laboratory manual is readily available before the experiment session.
U2	Layout	The layout and design of the chemistry laboratory manual are appropriate to help understand the content clearly.
U3	Activity	The number of experiments provided in the laboratory manual is sufficient.
U4		Conducting chemistry experiments provides joyful experiences.
U5		The design of experiments incorporates individual, pair, and group work.
U6	Skill	The design of experiments includes chemistry lab skills that I need to practice.
U7		The design of experiments in the laboratory manual provides students to acquire basic chemistry laboratory skills.
U8	Language	The language used in the chemistry laboratory manual is suitable for explaining how to conduct the experiments.
U9		The language used in the chemistry laboratory manual is at the right level for my current English ability.
U10	Content	The experiment procedure is easy to follow.

U11		Adequate safety laboratory information is included.
U12		The chemistry laboratory manual suits non-science students to do basic chemistry experiments.
U13		The experiments list is well organised and aligned with the topics in the syllabus.
U14	Overall Consensus	The laboratory manual raised my interest in learning chemistry.
U15		I would recommend reading this chemistry laboratory manual before conducting experiments.
Motivation		
M16	Relevance	The laboratory manual is relevant to helping me learn chemistry.
M17	Attention	The laboratory manual captures my attention to do experiments.
M18	Confidence	I am confident that using the laboratory manual will help me to do the chemistry experiment well.
M19	Satisfaction	I am satisfied with the laboratory manual.
M20	Motivation	I am motivated to use the laboratory manual to do experiments.

Data Collection and Analysis

The survey was administered following completion of all experiments and findings, allowing students to provide feedback based on actual familiarity with the laboratory manual. Responses were collected through Google Forms over a three-week period. The link to access the form was distributed by lecturers, and the purpose of the survey was explained to all students via WhatsApp groups and in class. A brief instruction to answer the questionnaire was also provided at the beginning of the survey form. A descriptive analysis method was applied to demographic, usability, and motivation items. For usability and motivation items, the average mean scores were calculated and the interpretation of the average means scores was conducted by using the scales provided by [31]; (1) Strongly Disagree (1.00-1.49), Disagree (1.50-2.49), (3) Neutral (2.50-3.49), (4) Agree (3.50-4.49) and (5) Strongly Agree (4.50-5.00). At the same time, inferential analysis was applied to motivational items in order to assess the correlation between the design of the chemistry laboratory manual and students' motivation in learning chemistry.

The results were calculated and presented using Statistical Package for Social Sciences (SPSS) and Microsoft Excel 365. Pearson's correlation (r) was employed to examine the magnitude and direction of the correlations among the item measures in the dataset. According to [32], correlation coefficients (r) near +1 suggest a strong positive relationship, values near -1 indicate a strong negative relationship, and values near zero indicate the absence of a significant linear relationship at a significant level of $p<0.01$.

RESULTS

Demographics

Over a span of 14 weeks, students went through lectures and laboratory experiments for the CHM101 course. Data collection was performed using Google Forms between weeks 13 and 15, after all the practical sessions were completed. Seventy-six students responded to the survey, or approximately 92 percent of all students enrolled. In all four locations, response rates were above 80 percent, with full participation from Kuala Pilah (KP) and Mukah (M). The most respondents (51 percent) hailed from KP, followed by Permatang Pauh (PP) (29 percent), Pasir

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Gudang (PG) (16 percent) and Mukah, M (4 percent). In terms of gender, 63 percent of respondents were female, and 37 percent were male. Table III shows the number of students responding to the survey based on location.

Regarding their academic background, all respondents obtained above-average grades (B and above) for science subjects in their secondary school examination (Sijil Pelajaran Malaysia [SPM]). But just 50 percent of respondents received an above-average mathematics score. This discrepancy implies that students might face potential barriers in their mastery of chemistry concepts because of the importance of mathematical proficiency in performing chemistry-relevant calculations.

Table III. Response Rate Based On Location (Source: Author’s Own Data (2025).

Location	Total Respondent	Total Student	Response Rate	Cumulative Response
Kuala Pilah (KP)	39	39	100%	51.3%
Mukah (M)	3	3	100%	3.9%
Permatang Pauh (PP)	22	26	85%	28.9%
Pasir Gudang (PG)	12	15	80%	15.8%
Total	76	83	-	100%

The study investigated the interest in learning chemistry among the respondents and found that the majority (96 percent) had a positive attitude towards chemistry. The third class of students emulated the previous two, with only three students (4 percent) expressing no interest in chemistry.

A reliability analysis of the 20 survey items was performed to ascertain the internal consistency. The reliability measured with the Cronbach's alpha was 0.961 and it was a high level (Table IV).

Table IV. Correlation Value (Source: Author’s Own Data (2025).

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.961	0.962	20

Usability and motivation

Pertaining to motivation, the variables that were strongly correlated with the four dimensions of motivation in the ARCS Model which are Attention, Confidence, Relevance, and Satisfaction were reported. Figure 2 illustrates the correlation model of usability items based on the ARSC model. The constructs of usability and motivation were measured by means of survey answers. Descriptive statistics revealed a mean usability of 4.32 (SD = 0.55537) and motivation of 4.34 (SD = 0.57764) as presented in Table V, such that the students agreed that the laboratory manual facilitated their learning and engagement.

Table V. Mean Score And Std. Deviation Usability And Motivation (Source: Author’s Own Data (2025).

	N	Mean	Std. Deviation	Interpretation
Usability	76	4.32	0.55537	Agree
Motivation	76	4.34	0.57764	Agree

Table VI indicates the correlation coefficient (r) between variables in the study. The analysis of correlation indicated moderate to strong correlations among all usability and motivation variables. U1 (Practical consideration; students readily before the experiment session) and U4 (Activity: Conducting chemistry experiments provides joyful experiences) shared the weakest correlation (r=0.303, p<0.01). The highest significant pairwise correlation (r=0.796, p<0.01) was between U4 (Conducting chemistry experiments provide joyful experiences) and U5 (design of experiments with individual, pair and group work). It shows that there is a need to enhance student interest in chemistry through active experimentation, a design of relevant engagement from this study.

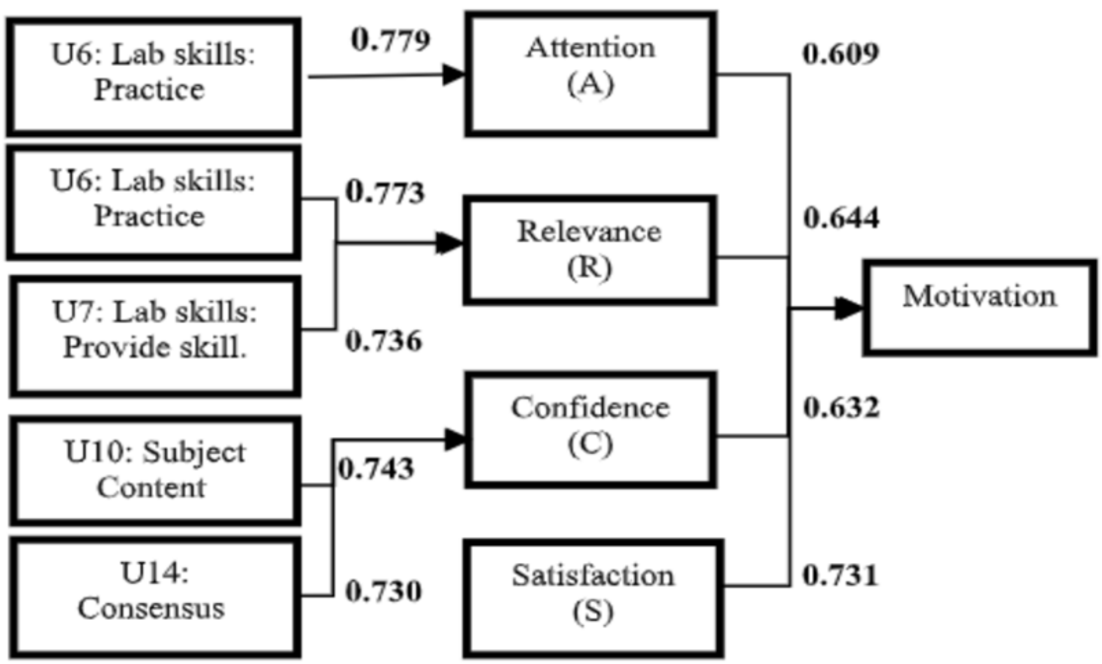

Figure 2 Correlation model of usability items based on the ARSC model.

Additionally, the variables strongly correlated with the four dimensions of motivation in the ARCS Model, which are attention, confidence, relevance, and satisfaction, were reported. The results demonstrated that U6: Laboratory Skills (The design of experiments includes chemistry lab skills that I need to practice) had a positive, strong correlation with both M17: Attention (r=0.779, p<0.01) and M16: Relevance (r=0.773, p<0.01). Another variable that also had a positive, strong correlation (r=0.736, p<0.01) with M16: Relevance was U7: Laboratory Skills (The design of experiments in the laboratory manual provides students with basic chemistry laboratory skills).

Meanwhile, for M18: Confidence, two variables demonstrated a positive, strong correlation with M18: Confidence, which was U10: Subject Content (The procedure of the experiments is easy to follow.) (r=0.743, p<0.01) and U14: Consensus (The laboratory manual raises my interest in learning Chemistry) (r=0.730, p<0.01).

However, none of the variables positively or strongly correlated with U19: Satisfaction. Nonetheless, a strong positive correlation was recorded between Motivation and Satisfaction (r=0.731, p<0.01), while positive moderate correlations were recorded between motivation and other dimensions: Attention (r=0.609, p<0.01), Relevance (r=0.644, p<0.01) and Confidence (r=0.632, p<0.01).

Overall, a good mean value result is consistent with the high correlation between usability and motivation. Table VII shows the correlations between usability and motivation. For usability, the average mean scores for all the constructs were used for the analysis. The results indicate that usability had a strong positive correlation with

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motivation (r=0.877, p<0.01). It is empirically evident that the design of the chemistry laboratory manual is usable and essential in motivating students to use the laboratory manual to conduct experiments.

Table VII. Correlation Between Usability Of The Chemistry Laboratory Manual And Motivation In Learning Chemistry. (Source: Author's Own Data (2025).

Pearson Correlation	**Usability**	**Motivation**
Usability	1	.877**
Motivation	.877**	1
N	76	76
**. Correlation is significant at the 0.01 level (2-tailed).		

DISCUSSION

Mathematics is fundamental to many STEM fields, including chemistry, which underpins essential concepts and skills. Based on the results, difficulties in mastering mathematics in secondary school may result in a bigger challenge in mastering other STEM subjects. [33] and [34] reported similar opinions in their review articles. For instance, mathematical proficiency is necessary for chemical equations, stoichiometry, molarity, reaction rates, and thermodynamics calculations in chemistry. Moreover, inadequate math skills can limit students' problem-solving abilities and critical thinking, essential in scientific inquiry and experimentation. Students who cannot interpret quantitative data or perform calculations accurately may struggle to draw meaningful conclusions from experiments or understand broader scientific concepts.

It is found that Chemistry lab manual made significant contribution in student motivation and students learning up to satisfactory level. Both the overall usability and motivation scores indicate that students perceived the manual as useful and engaging. These results are consistent with previous research emphasizing the importance of well-structured laboratory manuals to enhance student engagement and learning outcomes [35] [36].

One important finding was the high correlation between motivation (attention and relevance) and laboratory skills. Active learning and the opportunity to apply concepts learned in a lecture deepen the understanding of the course material, as shown in the literature that reports active learning strategies increase student retention and understanding of relevant concepts [37] [38]. While conducting experiments in the laboratory, students face various problems and uncertainties. They learn to think critically, troubleshoot problems, and design ways to attain positive results. These problem-solving abilities translate to other elements of chemistry studies, allowing students to tackle hard, theoretical problems with greater confidence. These findings align with results reported by other publications in the literature where adopting the practice and applying the approach for teaching introductory chemistry laboratory concepts results in significant learning gains and boosts in students' confidence levels [39]. Hence, laboratory skills provide a dynamic and interactive learning experience, fostering a deeper understanding and appreciation for the study of chemistry. Laboratory works promote attention, relevance, and a sense of accomplishment, leading to better learning outcomes and increased enthusiasm for the subject.

Moreover, the strong correlation between clarity in the experimental procedure (U10) and confidence (M18) highlights the critical role that providing clear, structured instructions in a laboratory manual. Well-known phrases like finds simple for search procedures, it tends to become more confident for students who carry out experiments with minimal guidance. Similar findings have been presented in studies evaluating instructional materials in the context of STEM education [16]. Research has shown that effectively designed templates and manuals can contribute to increasing students' self-efficacy, which in turn translates into an improved academic performance in laboratory-based courses [40][41].

The low correlation to satisfaction (U19) indicates that although the manual was helpful and attractive for students, other determinants such as individual teaching styles, chemistry principles, and personal interest suggested there was no clear causal relation with satisfaction in chemistry learning. Other factors may also come into play such as pedagogy, laboratory facilities, or previous interest in the subject. But previous work has also shown that motivation is not necessarily proportional to satisfaction, as many factors together make students engaged [42]. Further investigation into how laboratory infrastructure, instructor engagement, and peer collaboration impact satisfaction could provide deeper insights into student experiences in chemistry education [43].

Even so, this further analysis shows that laboratory manuals should be carefully tailored to complement different learning styles. Studies by [44] stress the importance of using various cognitive processing approaches when designing laboratory manuals, as students with restricting cognitive approaches interact differently with the material and consequently motivation, usability, and effectiveness must be taken into consideration when structuring the laboratory. In this context, the current study affirms that the usability of laboratory manuals relates positively to motivation, while also acknowledging the importance of using enhanced lab manuals to promote better conceptual chemistry understanding, consistent with [7] findings that laboratory learning improves conceptual retention.

In addition, [45] have argued that laboratory manuals should not only list procedures clearly but also engage students with reflective exercises that require them to connect what they observe with relevant theory. This has been demonstrated to develop students' metacognition and their ability to evaluate the results of their experiments critically. Although the current study lacks a metacognitive aspect, we recommend that future versions of the laboratory manual involve such an aspect in order to improve learning outcomes.

Finally, the association between laboratory work and students' confidence that they can learn chemistry is relevant to general conversations regarding self-efficacy in STEM education. Students become more confident if they experience successful laboratory results multiple times. The latest work by [46] provides evidence that connects to this walkthrough idea, showing that self-efficacy is a major predictor of students' willingness to engage with complex scientific content. Such a feature supports the concept that thoughtfully designed lab manuals should aim to be user-supportive, leading to a feeling of accomplishment and competence to help reinforce longer-term interest in the subject.

Overall, the present study identified four essential aspects that should be incorporated into manuals designed for the non-science student population, in addition to those displayed in recent literature: (1) Essential hands-on laboratory skills (2) Accessible explanation of basic chemistry concepts (3) Step – by - step breakdown of experimental procedures (4) Inclusion of strategies that can help engage students with chemistry. It will foster student engagement and motivation to ensure that the following components are included in any future editions of laboratory manuals. In addition, future research can investigate whether incorporating digital tools, such as interactive simulations or augmented reality, can further enhance laboratory learning experiences [47]. It is essential to increase their interest since they have just been introduced to chemistry, and they may continue learning it when they continue their studies to a higher level, which is a diploma in any science programme.

CONCLUSION

In conclusion, this study advocates for the effective integration of ESD in STEM education, particularly in the challenging subject of chemistry, emphasising its crucial role in fostering a sustainable future. Recognising chemistry as a central science, the study acknowledges the challenges faced by non-science students, making chemistry a demanding subject that requires effective teaching strategies. This research delves into the usability of a chemistry laboratory manual designed for non-science students in the Pre-diploma program at UiTM. This proves that laboratory manuals are helpful for students in performing experiments as they improve their laboratory skills, learning engagement and confidence in learning chemistry.

Usability, assessed through the ADDIE model, considers factors such as clarity, ease of understanding, and relevance. There is also a high positive correlation between usability and motivation, meaning that well-structured instructional materials will trigger a student's interest and satisfaction of teaching and learning. These findings also suggest that students are better served by laboratory manuals that include straightforward experiment procedures, foundational chemistry skills, and activities that capture students' interest.

Additionally, this study revealed that better pre-requisite achievement in mathematics translates to a better performance on chemistry tasks, hence, highlighting the relevance of mathematics for STEM graduates. While motivation correlated strongly with usability, satisfaction correlated significantly less strongly, indicating that other student factors influenced satisfaction beyond the manual itself. The research provides valuable insights for developing and improving instructional materials, with broader implications for advancing STEM education and contributing to a sustainable future.

RECOMMENDATIONS

The interpretation of the results of this study allows us to draw several recommendations to optimize the use of the chemistry laboratory manuals in favor of student motivation and learning. Student motivation can be enhanced with interactive and engaging elements in laboratory manuals. For instance, incorporating hands-on activities that promote critical analysis, and practical application could help students find relevance in chemistry. Promoting hands-on experiments is a great way to make students learn concepts by applying them on their own. Moreover, providing various instructional materials (for examples pictures, conceptual explanations, and real-world applications) could assist them in connecting theories to their real practice. Furthermore, several studies employing comparative design, focusing on approaches like technology-assisted lab manuals compared with traditional options, could help with determining the best practice in teaching. Lastly, qualitative feedback from students and instructors may help optimize the laboratory manual, so it caters to the needs of diverse learners. Educators should continuously work on improving usability and motivation of laboratory manuals to facilitate learning of non-science students in chemistry.

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TABLE VI. CORRELATION MATRIX OF EACH ITEM TO THE ARCS MODEL COMPONENTS (Source: Author's own data (2025).

Item Code	**U1**	**U2**	**U3**	**U4**	**U5**	**U6**	**U7**	**U8**	**U9**	**U10**	**U11**	**U12**	**U13**	**U14**	**U15**	**M16**	**M17**	**M18**	**M19**	**M20**
U1	1.000																			
U2	0.471	1.000																		
U3	0.358	0.580	1.000																	
U4	0.303	0.470	0.204	1.000																
U5	0.393	0.554	0.326	0.769	1.000															
U6	0.457	0.471	0.350	0.564	0.721	1.000														
U7	0.428	0.557	0.397	0.631	0.685	0.723	1.000													
U8	0.390	0.620	0.471	0.521	0.584	0.646	0.625	1.000												
U9	0.488	0.542	0.398	0.429	0.394	0.644	0.512	0.770	1.000											
U10	0.480	0.576	0.418	0.695	0.716	0.609	0.622	0.653	0.605	1.000										
U11	0.559	0.474	0.294	0.586	0.693	0.676	0.618	0.657	0.535	0.690	1.000									
U12	0.460	0.500	0.248	0.506	0.504	0.467	0.382	0.517	0.550	0.614	0.533	1.000								
U13	0.566	0.557	0.421	0.478	0.548	0.603	0.618	0.598	0.597	0.673	0.646	0.455	1.000							
U14	0.418	0.497	0.301	0.738	0.707	0.670	0.616	0.650	0.606	0.766	0.603	0.570	0.590	1.000						
U15	0.512	0.594	0.461	0.485	0.528	0.560	0.513	0.630	0.636	0.603	0.495	0.362	0.744	0.691	1.000					
M16	0.522	0.592	0.400	0.538	0.625	**0.773**	**0.736**	0.611	0.667	0.608	0.607	0.407	0.669	0.635	0.619	1.000				
M17	0.449	0.531	0.271	0.609	0.591	**0.779**	0.664	0.575	0.652	0.593	0.651	0.523	0.576	0.646	0.561	0.775	1.000			
M18	0.484	0.451	0.443	0.609	0.604	0.619	0.564	0.614	0.676	**0.743**	0.600	0.457	0.627	**0.730**	0.661	0.715	0.734	1.000		
M19	0.405	0.637	0.455	0.515	0.579	0.623	0.530	0.610	0.502	0.625	0.585	0.416	0.500	0.583	0.439	0.635	0.600	0.604	1.000	
M20	0.361	0.583	0.342	0.550	0.603	0.608	0.566	0.698	0.495	0.594	0.592	0.416	0.595	0.687	0.603	**0.644**	**0.609**	**0.632**	**0.731**	1.000